Temporal Changes of Air Pollutants and Land Surface Temperature around Jeddah Desalination Power Plant, K S A

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Abstract: Air pollution is a Global issue which has unlimited action on multiple scales, the main objective of this study is to investigate the temporal changes of air pollutants and land surface temperature around Jeddah desalination power plant. The mean monthly concentrations of Hydro-carbons, Carbon monoxide, Nitrogen oxides and sulfur dioxide during the year 2007 were estimated at different distances from the plant using the standard Gaussian plume model. The thermal bands of Landsat ETM+ were used to elaborate the land surface temperature (LST) at three dates (i.e. January, April, and August of 2007). Then the correlation between air pollutants and LST was implemented. The results indicate that the maximum concentration of Hydro-carbons, carbon monoxide, nitrogen and sulfur dioxides reach 1.76, 9.14, 182.20, and 963.32 $\mu g/m^3$ respectively. In general, it is noticed that these concentrations were obtained in August at a distance of 1300 – 1700 meter from the power plant. The results indicate the high correlation between LST and Hydro-carbons (0.9866), Carbon monoxide (0.9171), Nitrogen oxides (0.9338) and sulfur dioxides (0.9540).
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1. Introduction

As a consequence of their impact on the atmosphere, vegetation and human health, gases have received considerable investigation. About 90% of the anthropogenic emissions to the atmosphere are gaseous (Godish, 1997). The rapid population growth together with high rate of urbanization, industrialization and increase in motorized transport have resulted in an increased concentration of various air gaseous e.g. Hydro-carbons, Nitrogen and sulfur dioxides (Kean et al., 2000; Goyal et al., 2006; Khare and Nagendra, 2007). Recently, many researchers have investigated the emission of pollutants from power plants in several countries in the world (e.g. Pratil and Patil, 1990; Laird and Slon, 1993; Duncan et al. 1995; Hasanen et al., 1997; Lopez et al., 2005; Rodriguez et al., 2006). The air quality assessment around power plant generation in Saudi Arabia was studied by several researchers (e.g. Hesham, 2009; Al-Seroury & Mayhoub, 2011; Al-Seroury, 2012) they found that the main pollutants released from the power plants are Hydro-carbons, Carbon oxides, Nitrogen and Sulfur dioxides. Temperature is one of the most significant meteorological variables influencing air quality in urban atmospheres as it directly affects gas and heterogeneous chemical reaction rates and gas-to-particle partitioning (Aw and Kleeman, 2003). The global average annual temperature will increased by 1.4 to 5.8 C° over the period 1990 to 2100 in addition to the 0.6 C° warming since 1860 (Wallington et al., 2004). The current work aims to investigate the temporal changes of air pollutants and land surface temperature (LST) and assesses the association between air pollutants and land surface temperature around Jeddah desalination power plant. The Geographic Information System (GIS) and remote sensing data were implemented in this study.

2. Materials and methods

Study area

Jeddah Desalination Power Plant is located to the west of Jeddah city (Figure 1), the power plant stack is bounded by Latitude 21°33'4.26"N and Longitude 39° 6'53.29"E. According to NCDC, (2010) the area around Jeddah Desalination Power Plant is characterized by seasonal climatic condition. In winter onshore, air temperatures differ from 25 C° to about 12 C° while in summer the air temperatures differ from 35 C° to about 25 C°. The maximum and minimum air temperatures recorded in recent years (2005 – 2011) in the area are 49 C° in May and 6 C° in February respectively. Relative humidity varies throughout the year with average values between 65% and 70% in winter and from 50% to 55% in summer. The average annual rainfall taken over a four year period is 3.2 mm. The prevailing wind is throughout the year from North/Northwest with average wind speed of 15 knots.

Satellite data

Three available Landsat ETM+ image (LE71700452003010SGS00) acquired on January, April, and August 2007 has been used in his study. The ETM+ image contain 7 bands of spectral data represents the visible, infrared and thermal spectrum. The Scan Line Corrector (SLC) of the Landsat 7 was failed in May 31, 2003, creating a scanning pattern of

wedge-shaped gaps. The Landsat still to gain data with the SLC-off, generating images of about 22% missed data (Storey et al., 2005). To improve the capability of the images produced after May 2003, the SLC-off data could exchange with calculated values from the histogram-matched scenes using ENVI 4.7 software. The thermal bands of Landsat ETM+ (band 6) displays the amount of infrared radiant emitted from different surfaces. The long infrared waves are radiations that are detected as heat energy; therefore, the thermal IR band well correlate with the temperature of the surfaces it scans (EOSC, 1994). The image was enhanced by using ENVI 4.7 software. To improve the contrast and enhancing the edges, the images were stretched using linear 2%, smoothly filtered and their histograms were matched according to Lillesand and Kiefer (2007). The atmospheric correction was done to reduce the noise effect using FLAASH module. Image was radiometrically and geometrically corrected to accurate the irregular sensor response over the image and to correct the geometric distortion due to Earth's rotation (ITT, 2009).

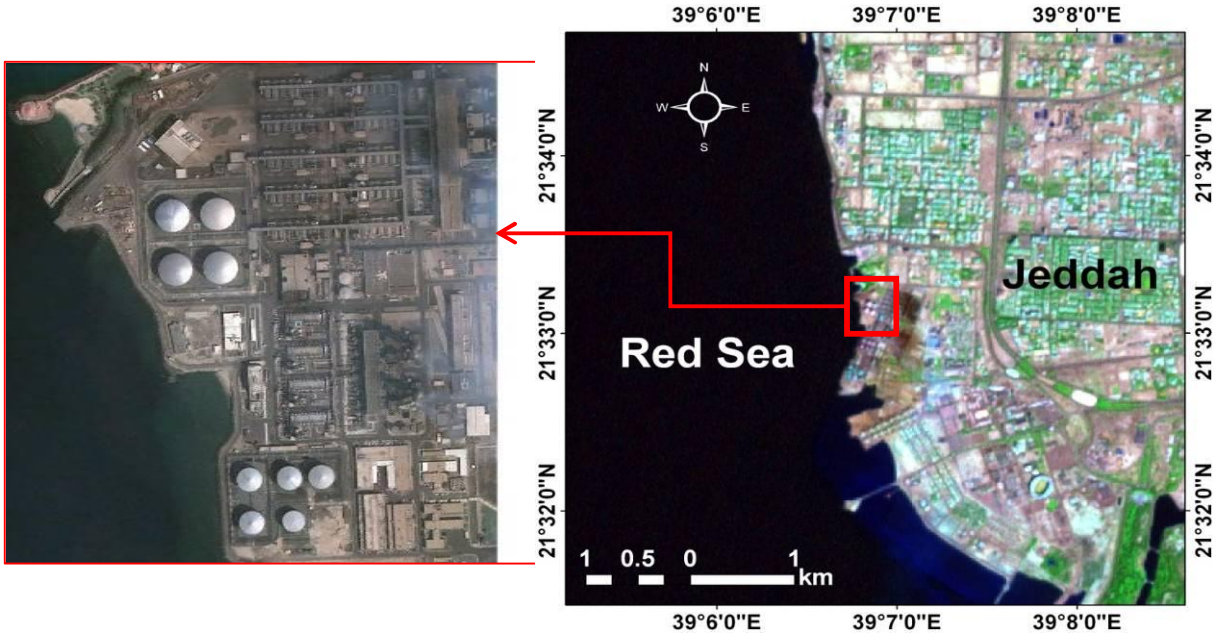

Figure 1. Landsat ETM+ (2007) of the study area (right), Jeddah Desalination power plant as appear on Google earth (left)

Estimating Land surface Temperature (LST)

Satellite detectors acquire thermal data and store it as digital numbers (DN) with a range of 0 - 255. The DN values were transformed to temperature (in Celsius) using band 6.1 of all available ETM+ images as follows:

- Converting the DNs to radiance values:

CVR= G *(CVDN) + B (eq 1)

Where, CVR is the cell value as radiance, CVDN is the cell digital number, G and B are the gain and the bias obtained from the image header file, (NASA, 2002).

- Converting the radiance to degrees in Celsius: T = K2 / ln (K1 / CVR + 1)] – 273 (eq 2)

Where, T= temperature in Celsius, K1= 666.09 and K2= 1282.71, (NASA, 2002).

Estimating the concentration of pollutants

Considering the plume rise, and climatic condition the Gaussian plume model (GPM) has been used to estimate the concentration of pollutants from both ground and elevated sources (IAEA, 1982 & IAEA, 1996) The model used to calculate the monthly concentration of Hydro-carbons, Carbon monoxide, Nitrogen and sulfur dioxides at 30 sites located at different distances around the stack (i.e. 1 – 2900 m) during 2007.

Spatial analysis

The concentrations of pollutants from 30 sites with the thermal layers were used in GIS to represent the association between the maximum concentrations of pollutants and land surface temperature by using the spatial analyst of Arc-GIS 9.3 software.

3. Results and Discussion

Air pollutants concentration

Tables 1, 2 and 3 represent the ground level concentrations of pollutants (Hydro-carbons, Carbon monoxide, Nitrogen and sulfur dioxides) at various distances from Jeddah Desalination power plant in January, April and August 2007. The data indicate the concentration of Hydro-carbons differ from 0.001553 to 1.713922 µg/ m^3. Carbon monoxide concentrations differ from 0.008032 to 8.864824 µg/ m^3. The concentrations of Nitrogen and sulfur dioxides range from 0.846192, and 0.160048 to 933.9126 and

176.6389 µg/ m^3 respectively. It is seen that the highest values of pollutants were observed at a distance of 1500 m during August while the lowest were measured at a distance of 500 m in January. The levels of pollutants were nil closed to the stack of the power plant (0 – 500 m). The minimum concentrations of the pollutants were observed at 600 m from the stack. After 1700 meter from the stack the concentration of all pollutants decreased gradually with distance.

Table (1): Ground level concentrations (µg/m^3) of the pollutants at different distances from the stack, (Jan 2007).

No.	Distance from stack (m)	Pollutants			
		SO_2	NO_x	CO	HC
1	500	0	0	0	0
2	600	1.226683	0.232013	0.011644	0.002251
3	1000	445.4169	84.24551	4.227957	0.817432
4	1300	854.1597	161.5546	8.107799	1.567559
5	1500	908.4344	171.82	8.622982	1.682805
6	1700	881.3179	166.6912	8.365588	1.6174
7	2000	759.6235	143.6741	7.210449	1.394066
8	2300	629.3446	119.0333	5.973824	1.154977
9	2500	552.031	104.4104	5.239953	1.013091
10	2900	426.3093	80.63153	4.046585	0.782365

Table (2): Ground level concentrations (µg/m^3) of the pollutants at different distances from the stack, (April 2007).

NO.	distance from stack(m)	Pollutants			
		SO_2	NO_x	CO	HC
1	500	0	0	0	0
2	600	0.846192	0.160048	0.008032	0.001553
3	1000	412.3121	77.98412	3.913722	0.756678
4	1300	832.5647	157.4701	7.902817	1.527928
5	1500	916.957	173.4319	8.70388	1.697164
6	1700	881.8796	166.7975	8.37092	1.618431
7	2000	766.8956	145.0495	7.279476	1.407411
8	2300	638.632	120.7899	6.061981	1.172021
9	2500	561.4497	106.1918	5.329357	1.030376
10	2900	434.8789	82.25238	4.127929	0.798092

Table (1): Ground level concentrations (µg/m^3) of the pollutants at different distances from the stack, (Jan 2007).

NO.	distance from stack(m)	Pollutants			
		SO_2	NO_x	CO	HC
1	500	0	0	0	0
2	600	3.28379	0.621091	0.03117	0.006026
3	1000	543.801	102.8538	5.161833	0.997987
4	1300	908.57	171.8456	8.624269	1.667413
5	1500	933.9126	176.6389	8.864824	1.713922
6	1700	874.0245	165.3118	8.296358	1.604015
7	2000	735.6672	139.1431	6.983053	1.350101
8	2300	601.2199	113.7139	5.706861	1.103362
9	2500	524.1787	99.14241	4.975575	0.961976
10	2900	401.5851	75.95523	3.8119	0.736991

Land surface temperature (LST)

The land surface temperature (LST) was estimated from the thermal bands of Landsat ETM+ images during the year 2007. Figures 2, 3 and 4 represent the land surface temperature over the Jeddah Desalination power plant in January, April and August of the year 2007. The data indicate that the LST differ from 14.4 to 27.5 C° in January, 15.5 to 31.6 C° in April and from 20.1 to 35.5 C°. In view of the land surface features collected from the Landsat ETM+

image (Bands 7, 4, 2) of the study area it is noticed that the high values of LST are associated with the industrial area and urban settlements. The low land surface temperature occupies the water bodies and vegetated surfaces.

Pollutants and LST association

The maximum concentrations of pollutants were observed for a site located at 1500 meter from the stack. The LST of this site was extracted from the thermal bands of the Landsat ETM+ in January, April and August during the year 2007. The LST values in the observed site differ from 19.5 C° in January, 26.3 C° in April and 31.6 C° August. The correlation between the pollutants (Hydro-carbons, Carbon monoxide, Nitrogen and sulfur dioxides) and LST have been done (Figure 5). The obtained results indicate a high correlation between the concentrations of air pollutants and the land surface temperature (LST). The obtained results show that the increase the LST the increase the concentrations of air pollutants, where the correlation coefficient (R^2) between LST and Hydro-Carbons (HC), Carbon monoxide (CO), Nitrogen oxides (NOx) and sulfur dioxides (SO2) are 0.9866, 0.9171, 0.9338 and 0.954 respectively.

This study indicates the temporal and special changes of pollutants concentration around Jeddah Desalination power plant. These changes are corresponding to the land surface temperature and the distance from the stack of the power plant. The results could be employed by the decision makers to avoid the immoral effect of pollutants to realize the environmental sustainability.

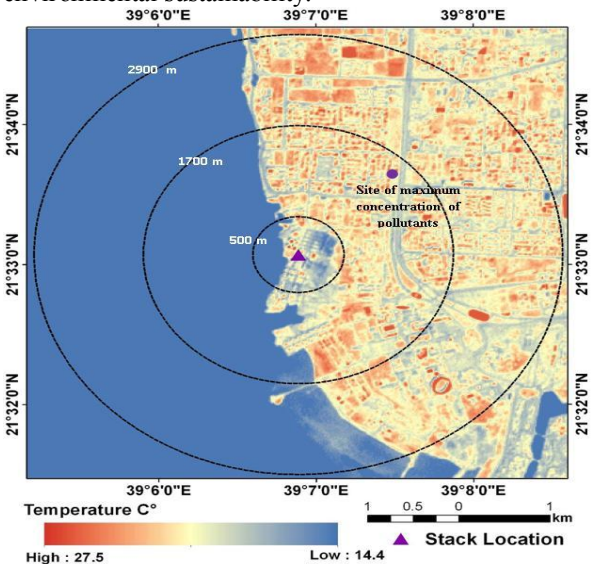

Figure 2. Land surface temperature in January 2007

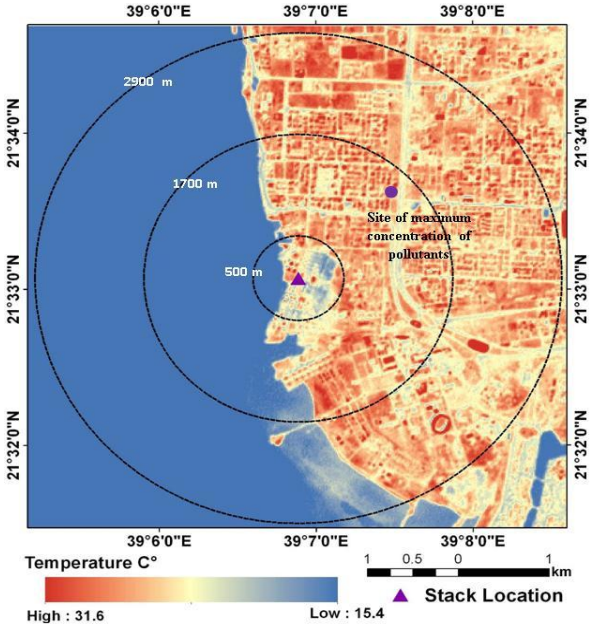

Figure 3. Land surface temperature in April 2007

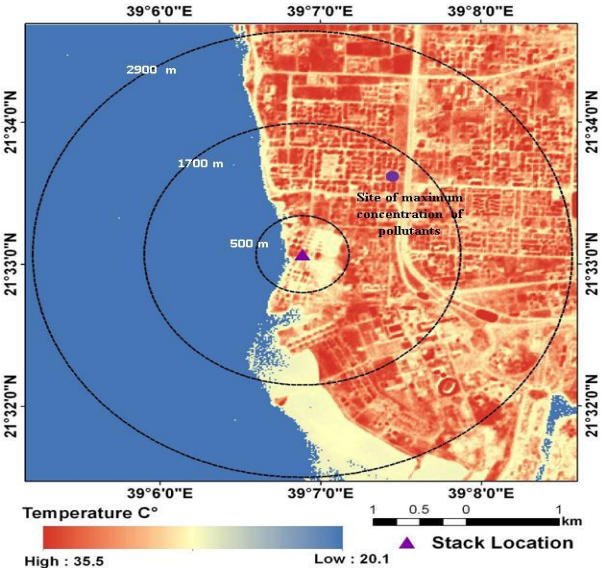

Figure 4. Land surface temperature in August 2007

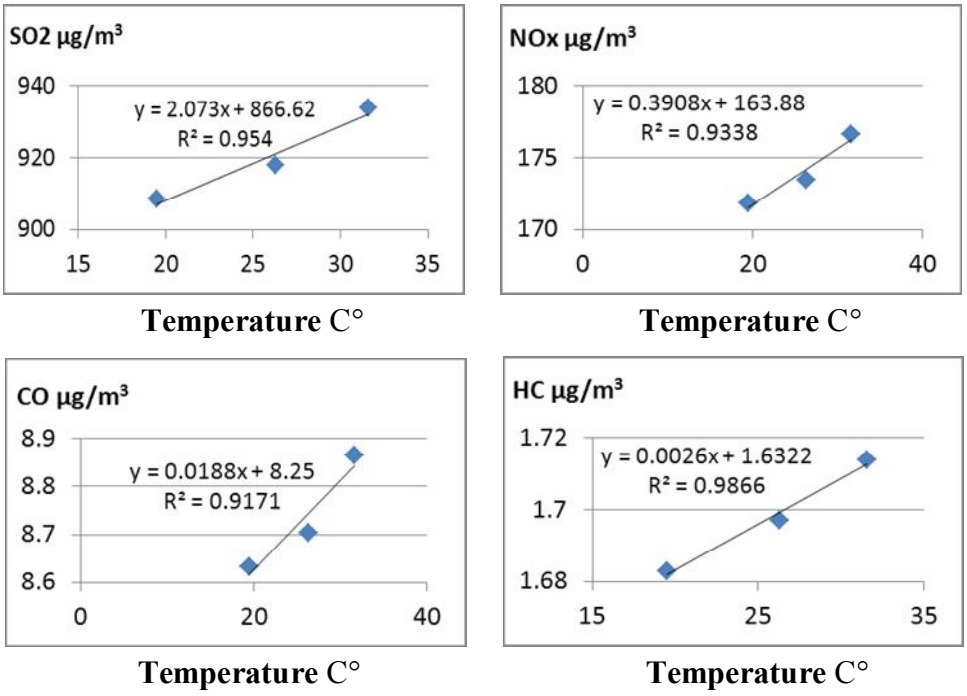

Figure 5. The correlation between LST and air pollutants

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